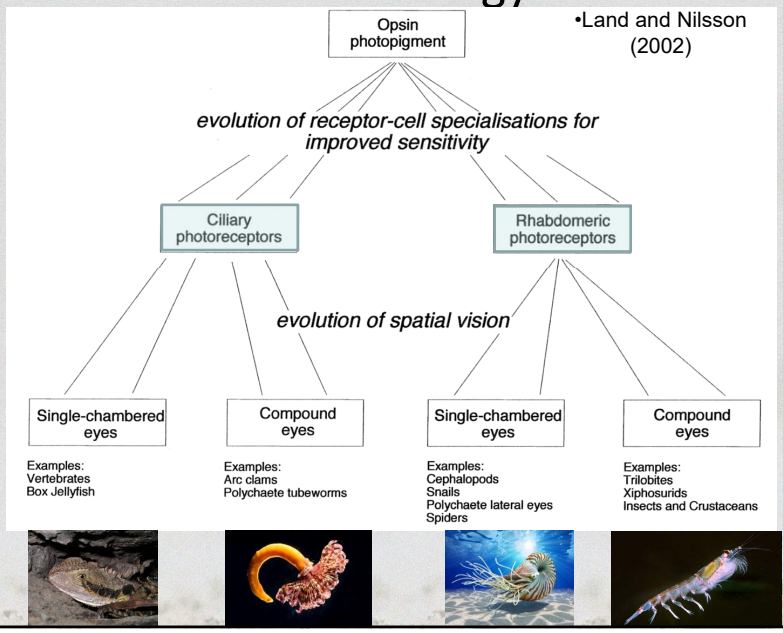
•1

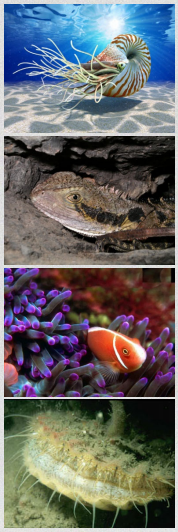
Evolution and homology

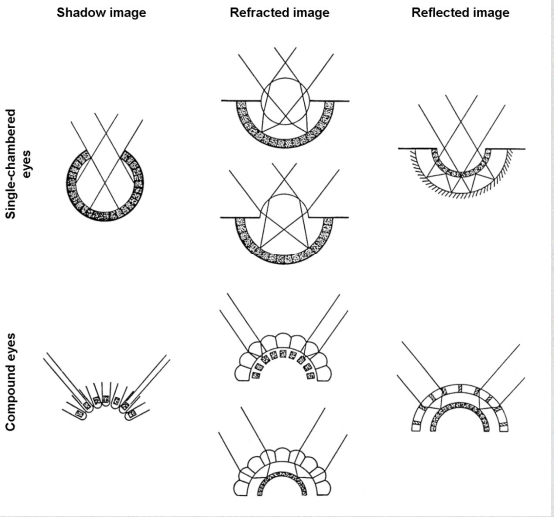


•Land and Nilsson (2002)

•2

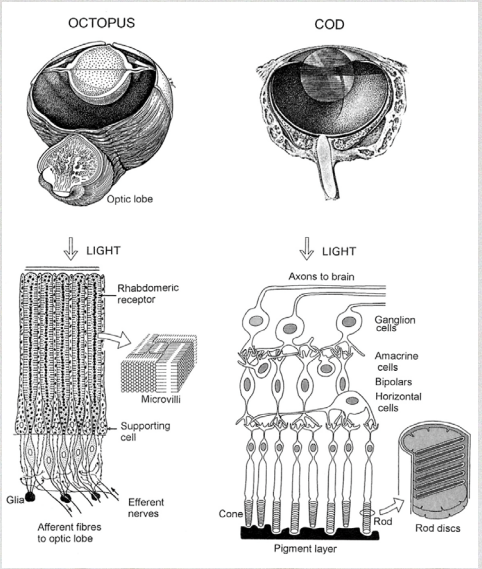
Animal eye designs





•3

Cephalopods *vs* vertebrates



Fish eye:

- Cornea present
- Multilayered retina
- Inverse retina
- Lens formed from layers of transparent fibre cells
- Ciliary receptors
- Colour vision (most)

Cephalopod eye:

- Cornea absent
- Retina is photoreceptor monolayer
- Everse retina
- Lens (where present) formed by cellular fusions
- Rhabdomeric receptors (microvilli)
- Colour blind

•4

Photoreceptor signals

Vertebrate photoreceptors **hyperpolarize** in response to light

Invertebrate (rhabdomeric) photoreceptors **depolarize** in response to light

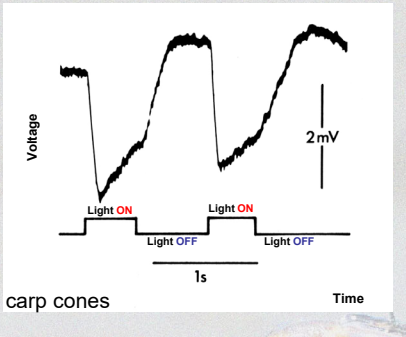
Dark (vertebrates)

- Cation channels open
- Dark current flows
- Cell membrane partially **DEPOLARIZED** (-10 to -40mV)
- Neurotransmitter release steady

Light (vertebrates)

- Cation channels closed
- Dark current reduced
- Cell membrane **HYPERPOLARIZES** (becomes more negative)
- Neurotransmitter release reduced

Vertebrate photoreceptors **hyperpolarize**



carp cones

•5

The Cambrian explosion About 570 - 530 mya

Triggered by spatial vision?

The evolution of eyes with good spatial vision coincided with this dramatic evolutionary explosion

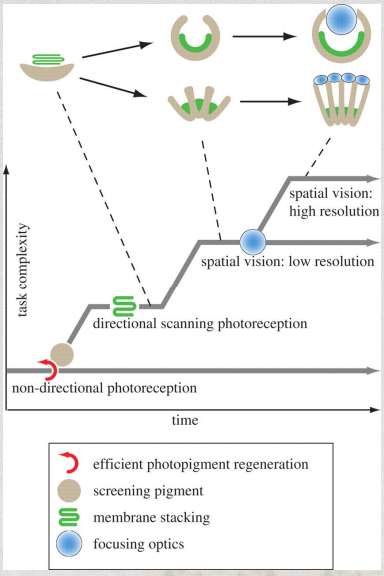
Appearance of nearly all modern body plans

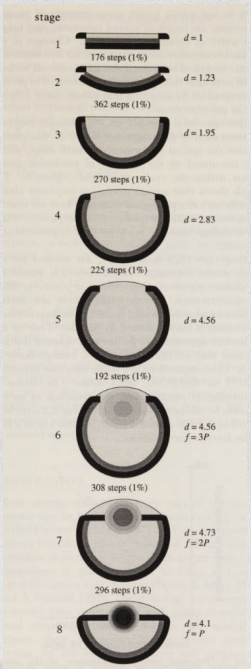
Arthropod *Xandarella* (China)

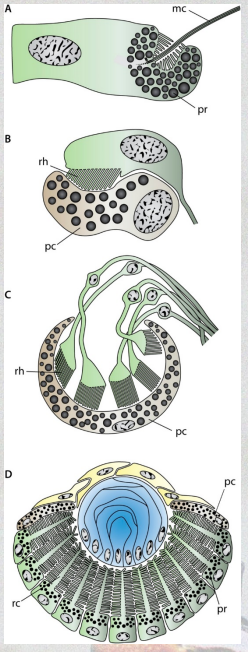
From Land & Nilsson 2012, Parker 1998

•6

Eye evolution



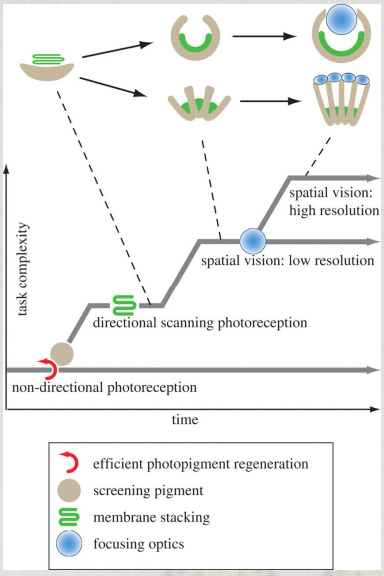


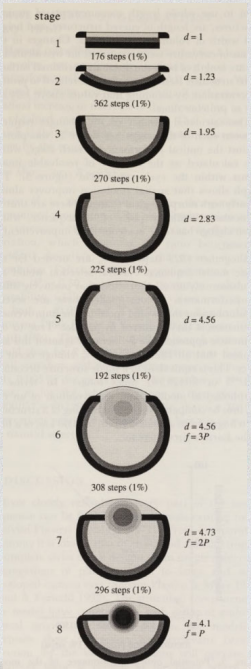


The evolution of eyes and visually guided behaviour, Volume: 364, Issue: 1531, Pages: 2833-2847, DOI: (10.1098/rstb.2009.0083)

•7

Eye evolution





Conservative estimate: 360,000 generations

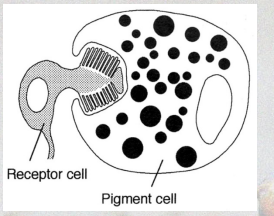
Suggests that eye structure is most likely driven by the need for vision rather than phylogeny

The evolution of eyes and visually guided behaviour, Volume: 364, Issue: 1531, Pages: 2833-2847, DOI: (10.1098/rstb.2009.0083)

•8

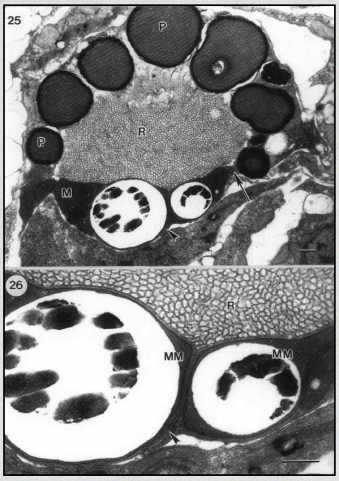
Evolution of spatial eyes: Eye spots e.g. larval trematode worms

- Simplest eye type
- Single photoreceptor
- Shielded by pigment cell
- Unidirectional but no spatial information

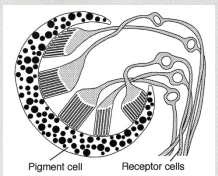


•9

Pigment pit eyes e.g. turbellarian worms



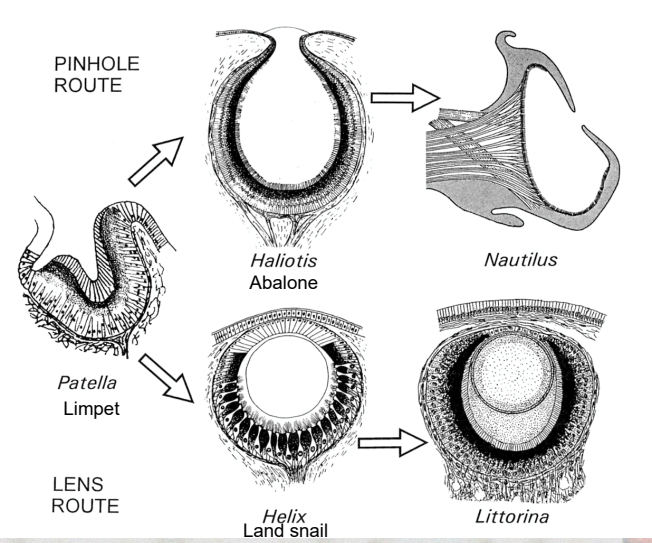
- Next level of functional complexity from eye spot
- (R) Receptors (microvilli assembled into rhabdoms) arranged in a pigment cup (P)
- Allows animal to discriminate between bright and dark areas of a crude image
- More spatial information than eye spot design
- Mitochondrial lensing (MM) in some species



Beklemischeviella contorta - from Watson (1998)

•10

Evolution of (some) Mollusc eyes



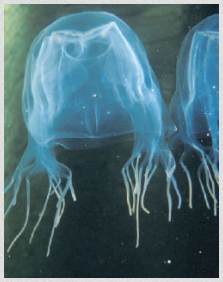
•11

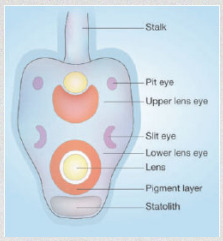
Pinhole eyes - *Nautilus*

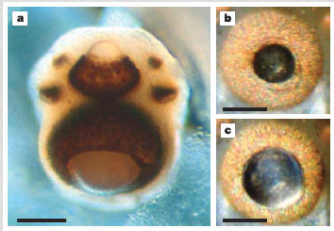
- Carnivorous Cephalopod
- Lives at 300 metres, surfaces at night
- Pinhole eye 10 mm diameter
- Pupil varies with light intensity from 0.4 to 2.8 mm diameter
- Poor resolution - angular subtense of receptor is 2.3° (~0.5 cycles/deg) for a 0.4 mm diameter pupil – similar to insect compound eyes
- **Image 400 times dimmer than fish eyes of comparable size**

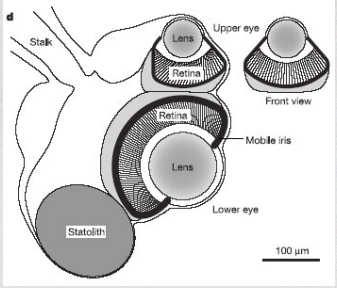
•12

Cubozoans (box jellyfish)









- Cnidarians
- Active swimming behaviour
- Rhopalium or 'sensory club'
- 6 eyes:
  - 2 lens eyes
  - 4 pigment pit eyes
- Lenses have graded RI
- Mobile pupil
- Single visual pigment → no colour vision?

•13